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Title: w18_plxa Viewgraphs

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w18_plxa Viewgraphs

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2/28/2019

w18_plxa Viewgraphs

- Flash results from LA-UR-18-30344

Results presented in conference poster:

T. Byvank, S. Langendorf, S. C. Hsu, P. Tzeferacos, Y. C. F. Thio, Assessment of High-β Magnetized Target Formation and Plasma-Liner Nonuniformities in Plasma-Jet-Driven Magneto-Inertial Fusion using the FLASH Code, 60th Annual Meeting of the American Physical Society Division of Plasma Physics (APS DPP 2018), Poster Session GP11, Portland, OR, November 6, 2018.

Background: Target Formation Quantities of Interest

Plasma Beta, $\beta = \Sigma_j n_j k T_j/(B^2/2\mu_0) \sim nT/B^2$

- Ratio of thermal pressure to magnetic pressure
- **GOAL: want $\beta > 1$**, thermally/flow-dominated

→High β limits MHD instabilities

(Ion) Magnetization, $\omega_i \tau_{ii} = \omega_i/\nu_{ii} \sim BT^{3/2}/n$

- Ratio of ion cyclotron frequency to ion-ion collision frequency
- **GOAL: want $\omega\tau > 1$**, magnetized (*despite high-β)

→High $\omega\tau$ reduces thermal transport ⊥ to B, enhances confinement time

Lambda Gun, $\lambda_{gun} = \mu_0 I/\Psi_{pol} = 2\pi r B_\theta / \int_0^R 2\pi r' B_z dr' \sim B_\theta / r_{char} B_z$

- In preliminary studies, we have $B_{\theta MAX} = 0.7$ T and we vary $B_{z0} = 0.004 - 0.4$ T

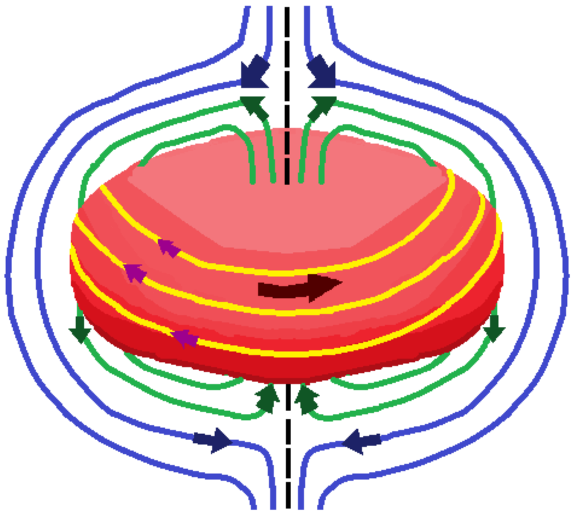
$\beta > 1$, $\omega\tau > 1$ is an interesting regime: thermally dominated and magnetized

Background: Lambda Gun Parameter

<u>Spheromak</u>

$\lambda_{gun} > \lambda_{crit}$

$\beta < 1$



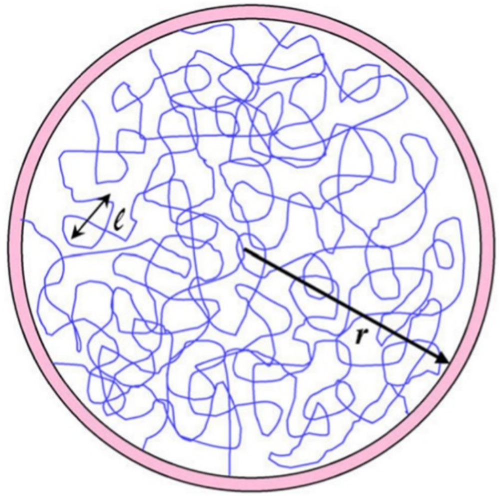
Red: Plasma
Blue: Outside B
Green: Poloidal B
Yellow: Toroidal B

Wikihelper2134, 2017

<u>**Goal for Target**</u>

$\infty > \lambda_{gun} > \lambda_{crit}$

$\beta > 1$, $\omega\tau > 1$



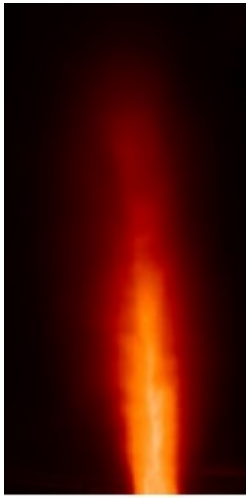
Tangled magnetic field
(length scale $\boldsymbol{\ell}$ >> electron mean free path $\lambda_{mfp,e}$)
can further reduce electron transport
and increase confinement time

Hsu 2018 JFE, DOI: 10.1007/s10894-018-0168-z

<u>Unmagnetized Plasma Jet</u>

$\lambda_{gun} = \infty$

$\beta >> 1$, $\omega\tau << 1$



Optical Emission Image

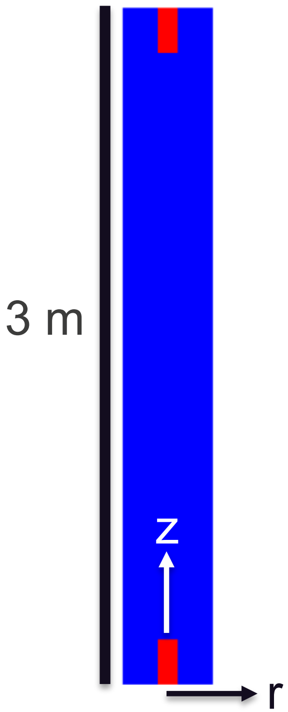
Hsu 2012 PoP
DOI: 10.1063/1.4773320

Varying λ_{gun} will scan parameter space to create the $\beta > 1$, $\omega\tau > 1$ plasma

Simulation Setup: Target Formation

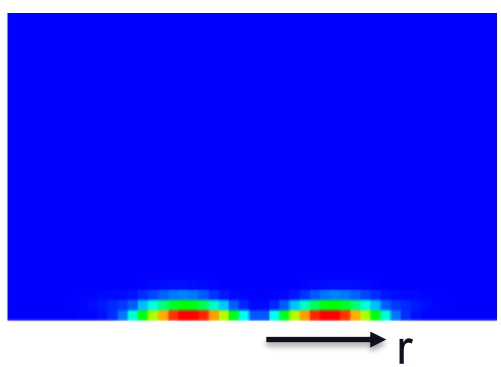
1) **Plasma jets (H, 10 eV, $5*10^{15}$ cm^{-3}) launched by $B_\theta(r,t) \sim \sin(r)*\sin^2(t)$**
2) **Jets advect $B_{pol}(r,z)$**
3) **Merging jets form magnetized target**
- **FLASH Simulation: 2D azimuthally symmetric (r-z plane) of 2 colliding jets**

Initial Density

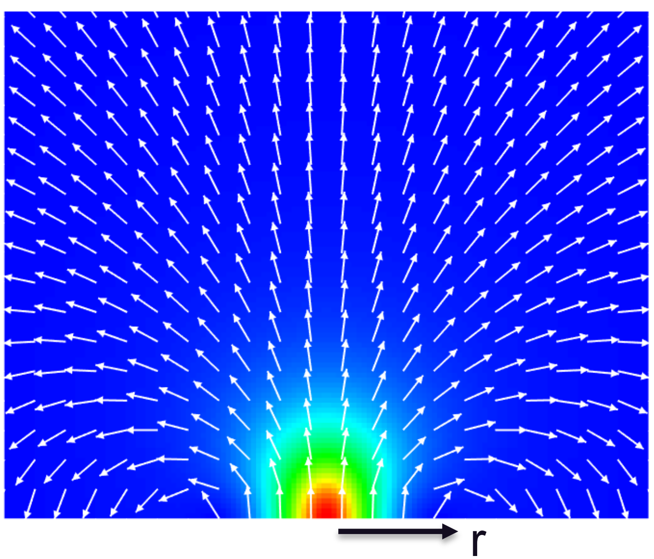


Zoom-In on Bottom Boundary

B_θ Drive

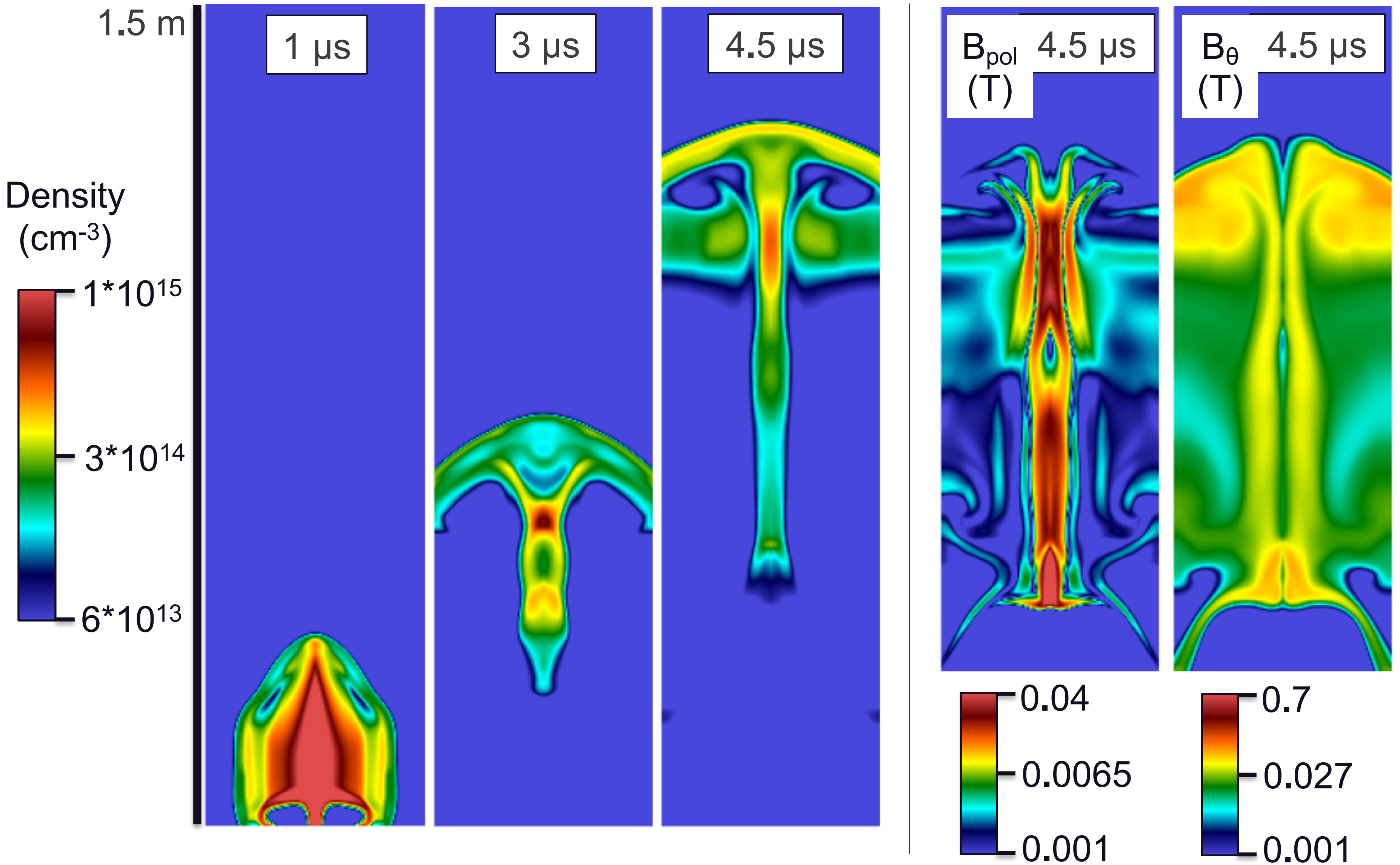


Initial Applied B_{pol}



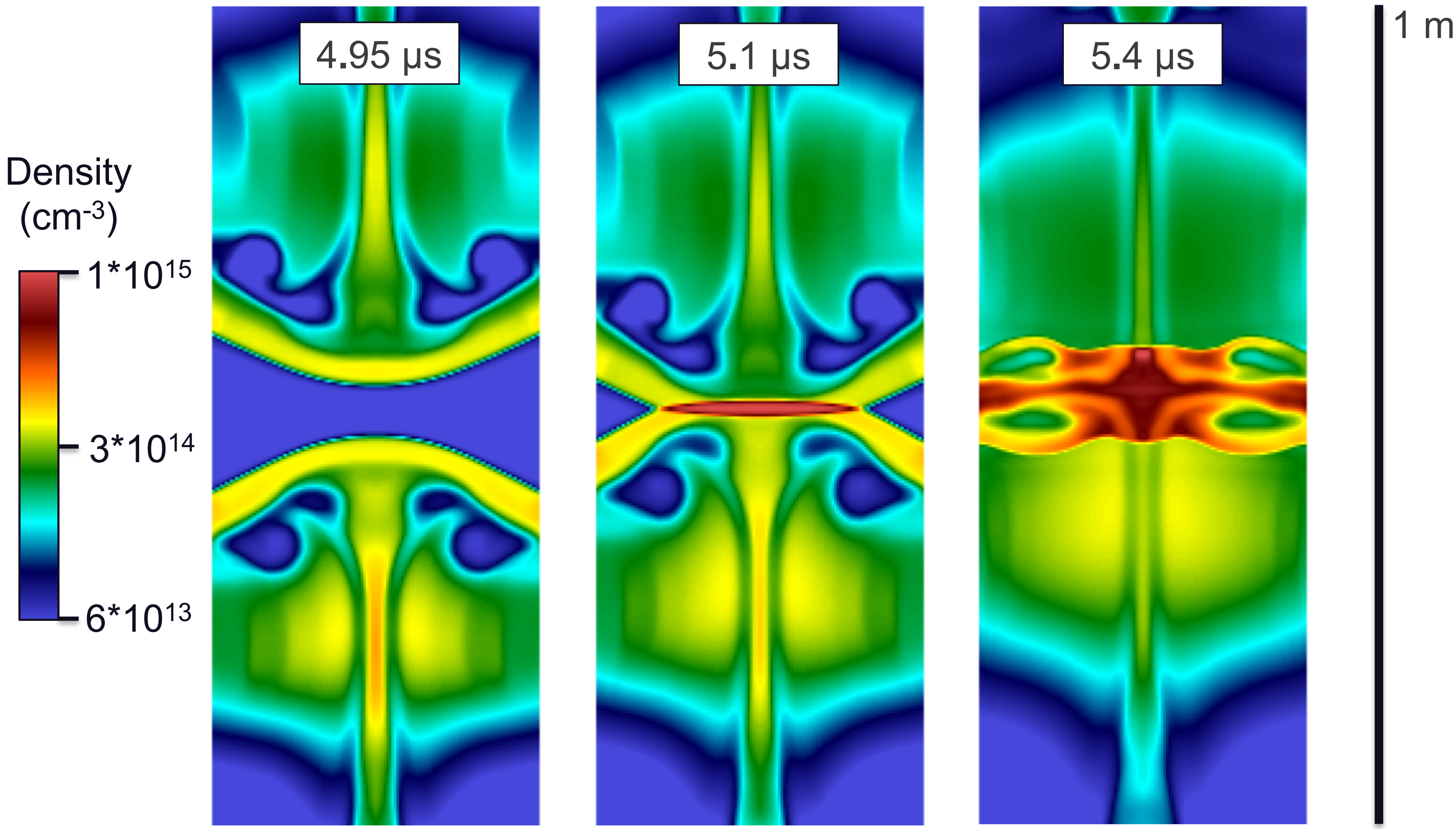
Color scales: **Red**: larger values, **Blue**: smaller values

Results: Target Formation– Time Evolution, Single Jet



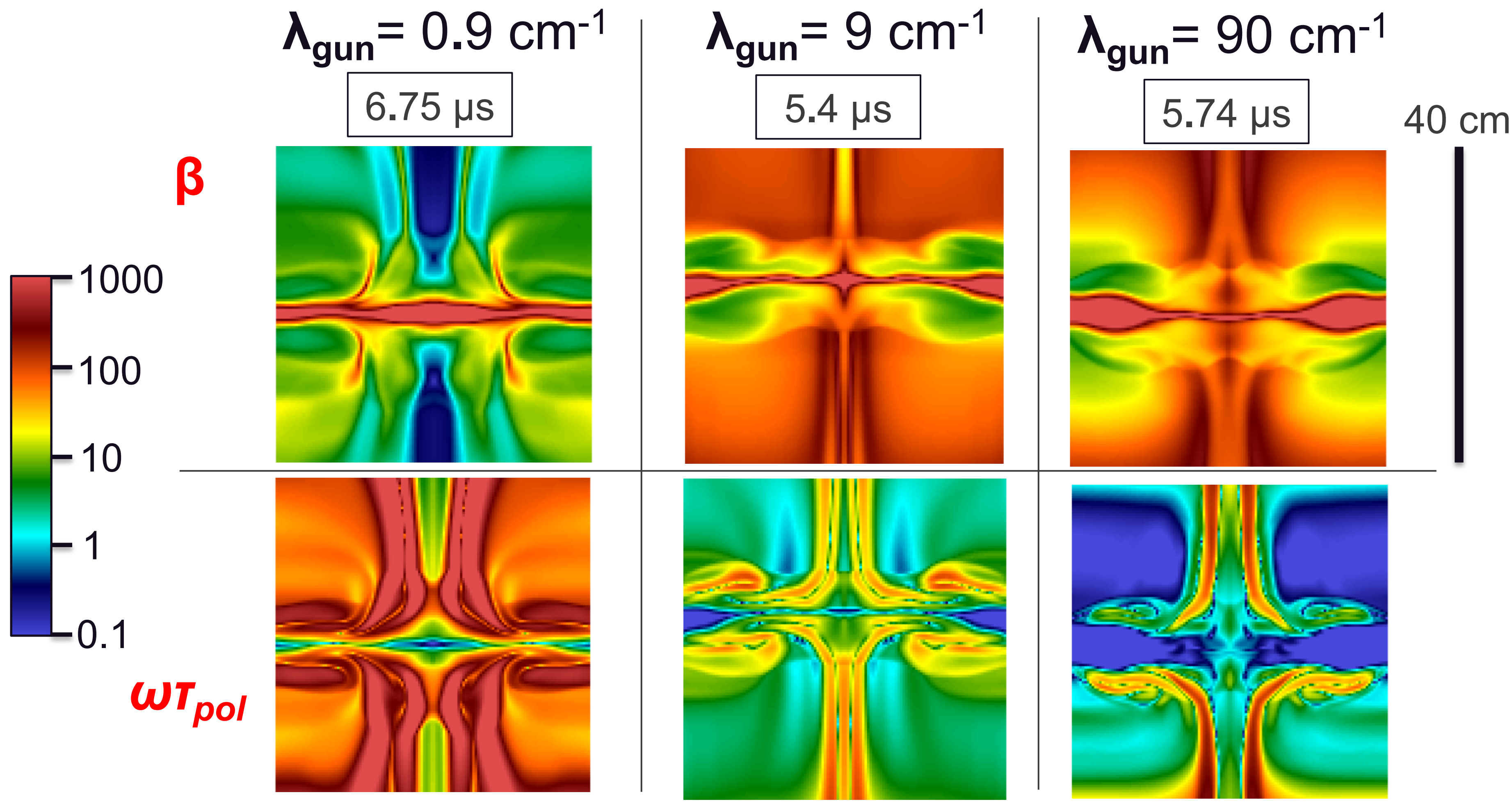
λ_{gun}= 9 cm^{-1}

Results: Target Formation– Time Evolution, Collision



λ_{gun}= 9 cm^{-1}

Results: Target Formation– Varying λ_{gun}



Note: here, est. $\lambda_{crit} \sim 3/r_{char} = 0.6$ cm^{-1}

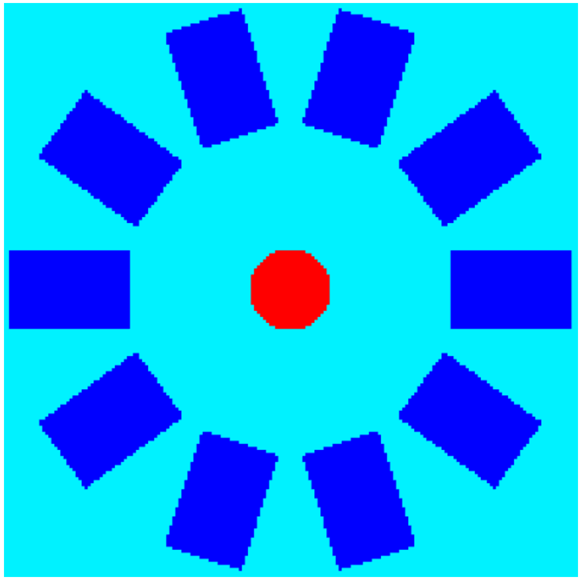
Various λ_{gun} values can create the β > 1, ωτ >1 plasma target

Simulation Setup: Liner Nonuniformities

Kim 2013 PoP
DOI: 10.1063/1.4789887

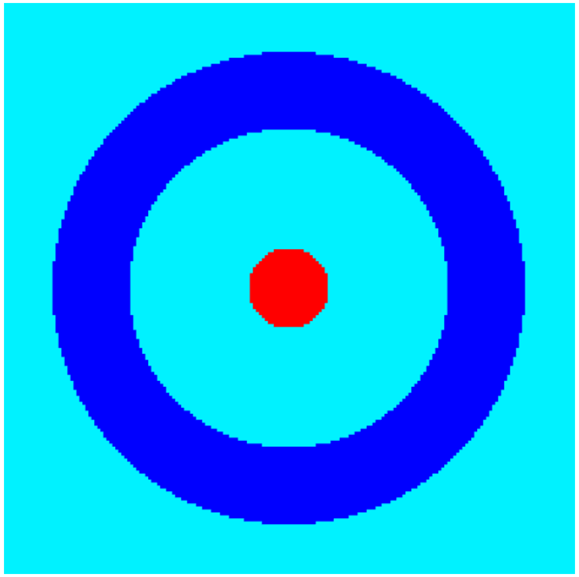
2D Discrete Jets

72 cm



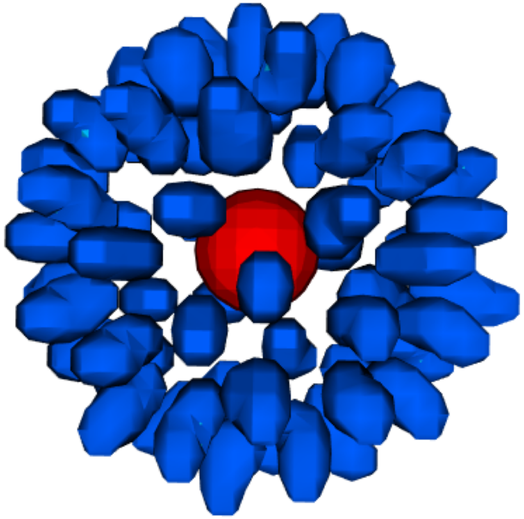
15 cm jet length

2D Uniform Shell



9.6 cm shell thickness

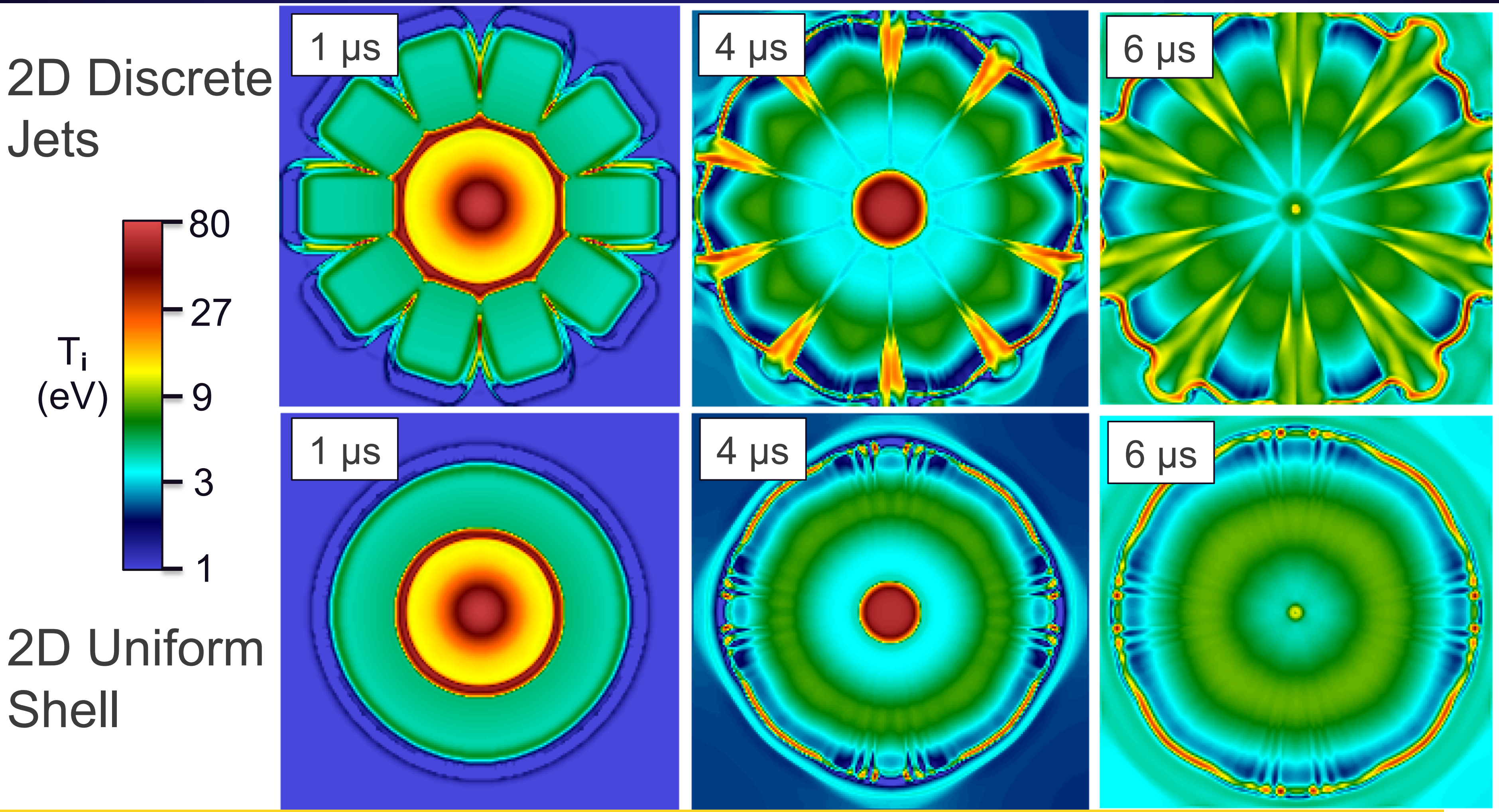
3D Discrete Jets (60)



- Keeping total liner mass constant, 50 km/s (inward), 1.5 eV, 10^{17} cm^{-3}
- Initial target: 100 eV, 10^{18} cm^{-3} → 3.2×10^{4} bar

Cyan: Chamber vacuum (He), **Blue**: Liner (Ar), **Red**: Target (H)

Results: Liner Nonuniformities– Shocks

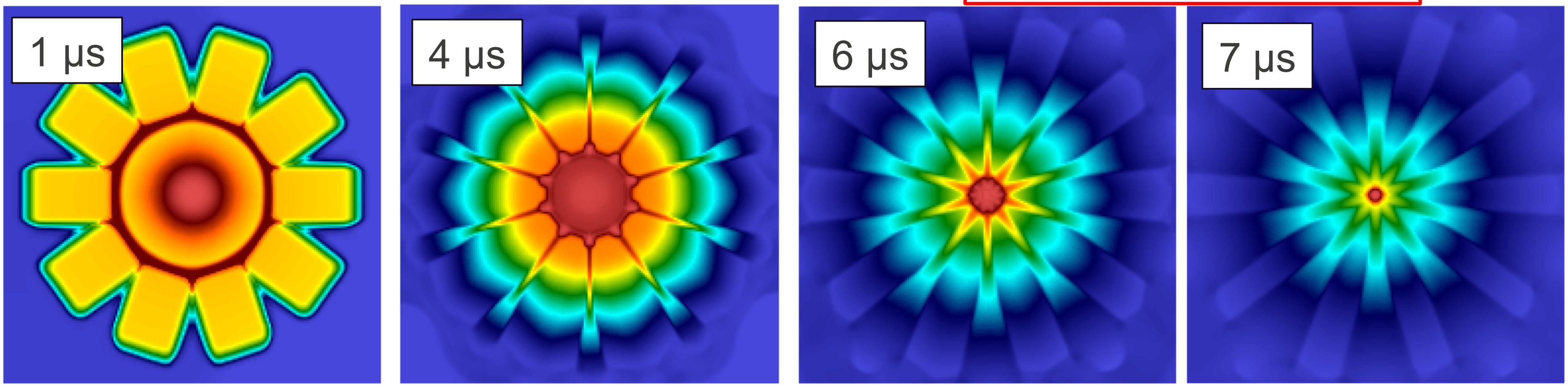


Merging of discrete jets creates shock structures. Question is: to what extent do these nonuniformities degrade the target compression?

Results: Liner Nonuniformities– Target Compression

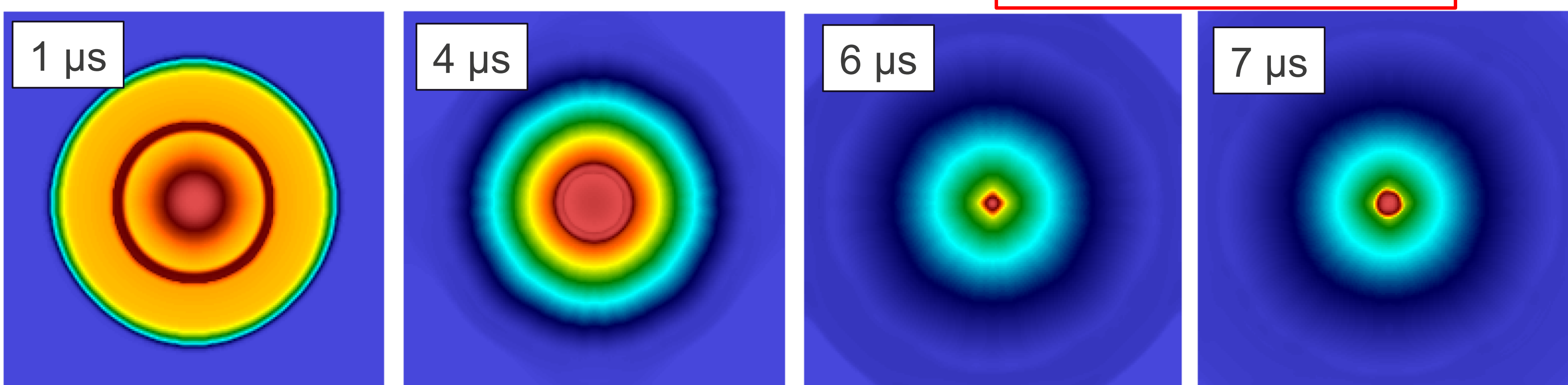
2D Discrete Jets– Pressure

P_{MAX}/P_{t0} = **22** at 6.9 μs



2D Uniform Shell– Pressure

P_{MAX}/P_{t0} = **25** at 6.1 μs



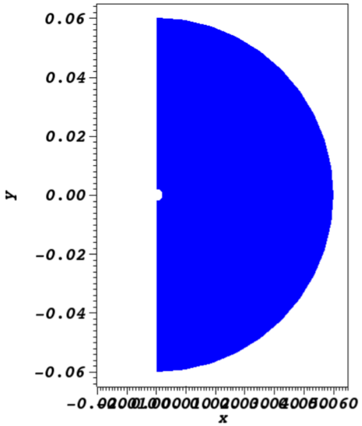
Want small liner thickness so it acts like a piston to compress the target.

USim studies of 2D MHD target compressions

- Task 4.2.5: 2D PJMIF simulations

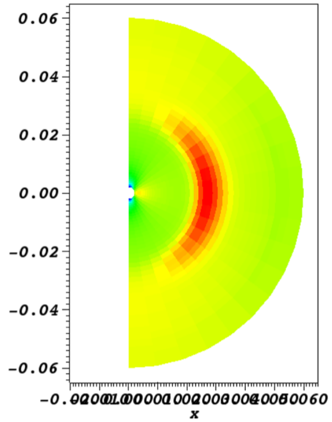
Bz

t=0



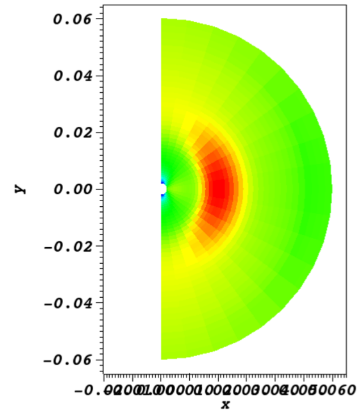
Blue contour~ 4T

t=0.05



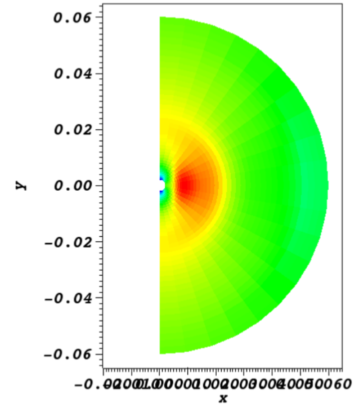
Red contour~ 6T

t=0.1



Red contour~ 7T

t=0.15 us

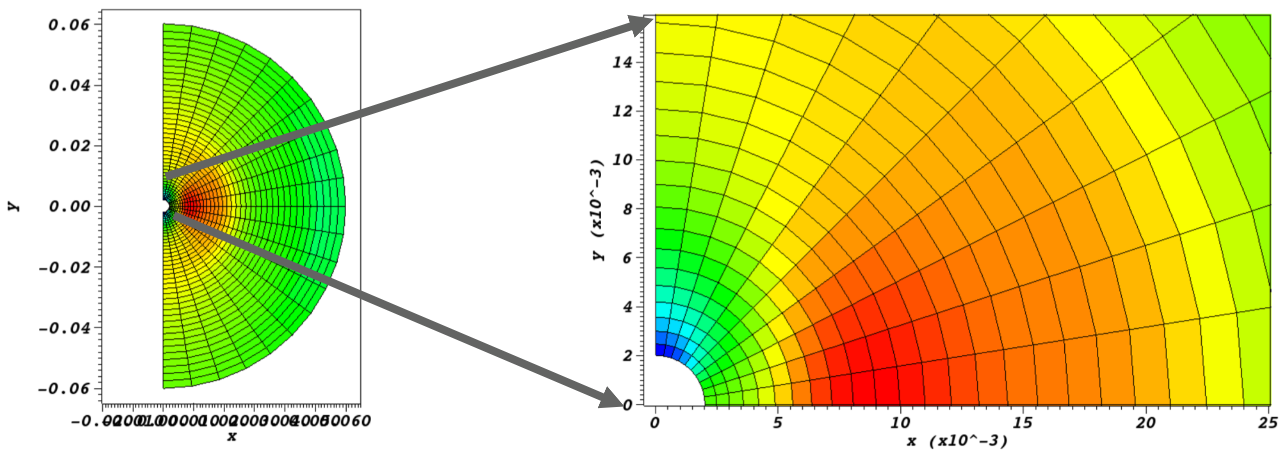


Red contour~ 9T

- We have the first simulations with axial magnetic field, consistent with (for example) embedding the target in a solenoidal field

USim studies of 2D MHD target compressions

- **Task 4.2.5: 2D PJMIF simulations**



- **LANL supercomputing resources allowed us to run with sub-mm grid resolution with less than 30 min turnaround time**